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Journal of Plant Nutrition
Publication details, including instructions for authors and subscription information:
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Online Publication Date: 13 August 2002

To cite this Article Alva, A. K., Hodges, T., Boydston, R. A. and Collins, H. P.(2002)'DRY MATTER AND NITROGEN ACCUMULATIONS AND PARTITIONING IN TWO POTATO CULTIVARS',Journal of Plant Nutrition,25:8,1621 — 1630

To link to this Article: DOI: 10.1081/PLN-120006047

URL: http://dx.doi.org/10.1081/PLN-120006047

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JOURNAL OF PLANT NUTRITION, 25(8), 1621–1630 (2002)

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DRY MATTER AND NITROGEN ACCUMULATIONS AND PARTITIONING IN TWO POTATO CULTIVARS

A. K. Alva,[1,*] T. Hodges,[2] R. A. Boydston,[1] and H. P. Collins[1]

[1]USDA-ARS-PWA, Vegetable and Forage Crops Research Unit, 24106 North Bunn Road, Prosser, WA 99350
[2]Agricultural Systems Consultant, 14314 SW Allen Blvd. #317, Beaverton, OR 97005

ABSTRACT

Potato plant dry matter and nutrient accumulation and partitioning patterns into various parts of the plant are important to fine tune management practices that optimize the nutrient uptake efficiency and tuber production. Accumulation and partitioning of dry matter and nitrogen (N) during the growing period were evaluated in this four year study for two potato cultivars in high yielding production conditions in the Columbia Basin production region in Washington, under irrigated farming. Studies were conducted on a Quincy fine sand, which represents a typical potato production soil in this region. A full season indeterminate potato cultivar (Russet Burbank) and an early maturing determinate cultivar (Hilite Russet) were used in this study. Partitioning of assimilates into the tuber was similar for both cultivars. The

*Corresponding author. E-mail: aalva@pars.ars.usda.gov

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tuber weight accounted for 76 to 87% of total plant weight, while that of stem and leaf weight accounted for 3 to 11, and 9 to 13%, respectively. Tuber weight increased rapidly during 60 to 100 days after planting. Nitrogen content in the tuber, in relation to the total N in the plant, accounted for 81 to 86, and 83 to 89%, for the Hilite Russet and Russet Burbank cultivars, respectively. Nitrogen in the leaves comprised 6 to 18%, and in the stem 3 to 5% of the total plant N. Prior to senescence of the vines, total N in the plants (excluding roots) accounted for up to 350 kg ha^{-1}. At this growth stage, the N in tubers, leaves, and stems represented 68.6, 19.4, and 12.0%, respectively. The above information is useful for N management with the knowledge of soil residual N and availability of N from mineralization of crop residue during the crop growing season.

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INTRODUCTION

Pattern of potato plant growth over the entire growing season and relative distribution of dry matter and nutrients among different plant parts are important parameters to understand and modify the management practices in an effort to improve the nutrient uptake efficiency, yield and quality of tubers. These data can be used to develop simulation models to predict potato growth and tuber production. Plant growth rates and nutrient availabilities in the soil influence the pattern and magnitude of nutrient uptake, and accumulation and partitioning of dry matter into different parts of the plant.[1–4]

Variations in climatic factors and varietal differences contribute to differences in growth patterns, and thus production potential. Kooman and Rabbinge [5] reported that early season potato varieties allocated a larger part of the available assimilates to the tubers early in the growing season as compared to the late season varieties. This, in turn, explains the shorter growth period and lower yields of early season as compared to that of the late season varieties. Adequate nutrient availability and uptake to support maximum growth rate of plants are important to attain the optimal production. Westermann and Kleinkopf [6] reported that a N uptake rate of 3.7 kg ha^{-1} day^{-1} was required by potato plants (Russet Burbank cultivar) to support optimal tuber yields.

Biemond and Vos [7] grew potato plants (cv. Bintgi) in 20 liter pots with pure sand and applied N at either 2.5, 8.0, or 16.0 g per plant. The dry matter content per plant was greater at the two high N rates as compared to that with low N rate treatment. Among the two high N rates, the dry matter per plant increased rapidly during 100 to 120 days for those that received 16 g N per plant. During 120 to 150 days, N uptake rate followed very closely with N rates that were

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applied 60 days after emergence. Unlike the plant total dry matter content, the harvest index (tuber weight as percent of total plant weight) showed marginal response to different N rates. At each sampling time beginning 40 days after emergence, the harvest index decreased with an increase in N rate. At crop maturity, the harvest index approached 86% across all N rate treatments. Therefore, although N rates influenced the harvest indices of both dry matter and N during the growing period, the N rate effects were nearly non-significant at crop maturity on the above two harvest indices. During 30 to 80 days after plant emergence, the increase in dry matter weight of the plant tops which received either 8 or 16 g N per plant, was four-fold greater than that of the plants which received 2.5 g N per plant. The tops dry weight began to decrease during 80 to 120 days after emergence in the plants which received 8 and 16 g N. The objective of this study was to evaluate the pattern of dry matter accumulation, and partitioning of dry matter and N during the growth period of a full season and an early maturing potato cultivars grown under high yielding conditions in the Pacific Northwest.

MATERIALS AND METHODS

Plant samples for dry matter and N partitioning were taken from a four year field experiment during 1992 through 1996. The experiment was conducted in a Quincy sand (mixed, mesic Xeric Torripsamments) in Benton County, WA. The details of the experiment are described in another paper,[8] in which the yield and tuber quality data were presented. Briefly, the experiment included two potato cultivars (Russet Burbank and Hilite Russet), two irrigation regimes, and three tillage treatments (conventional, modified, and reduced with flat planting). A linear move sprinkler irrigation system was used to deliver water either: (i) to replenish full evapotranspiration (ET); or (ii) to replenish only 85% of ET. Cut potato seed pieces were planted at a rate of 4.56 plants m^{-2} (45,600 plants ha^{-1}) at 15 cm depth. Recommended best management practices were followed.[9] The experiment was conducted with a randomized block design with four replications.

Four plants per plot were randomly sampled on a weekly interval beginning 32 days after planting until the plants attained maturity as evident from full growth of the tubers and decline in leaf weight due to senescence. The plant samples were divided into leaf, stem, and tuber; cleaned to remove all soil particles; dried at 70°C for 72 hours; weighed; ground to pass through a 40 mesh screen. The concentration of N in the plant parts was measured by the micro-Kjeldahl method. Using the N concentration and dry matter weight in each plant part, total N content was calculated for each plant part to determine the total N uptake.

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RESULTS AND DISCUSSION

The four years results showed similar response patterns with regard to dry matter accumulation and partitioning in different plant parts. For the convenience in discussion, we presented 1994 data as an example. Tuber weight increased rapidly during 60 to 100 days after planting and leveled off thereafter (Fig. 1). At final maturity of the crop, the tuber dry weight represented about 300 g per plant, and was slightly greater for the Russet Burbank as compared to that for the Hilite Russet cultivar. The rapid phase of leaf expansion and growth occurred from 30 days after planting and continued until about 100 days (Fig. 2). This was followed by a rapid decrease in leaf weight due to leaf senescence and collapse of the tops towards later part of the growing period until tuber maturity.

The pattern of dry matter accumulation and partitioning presented in this study followed the general pattern of dry matter partitioning reported by Westermann.[10] At full maturity of the crop, the tuber weight accounted for 76 to 87% of total plant weight, while the stem and leaf weights accounted for 3 to 11 and 9 to 13%, respectively (Fig. 3). Across all years, the final tuber weight as a proportion of the total plant weight was slightly greater for the Hilite Russet as compared to that for the Russet Burbank cultivar. Therefore, although the total tuber yield was greater for the Russet Burbank as compared to that for the Hilite Russet, the partitioning of total assimilates into the tuber was quite similar in both the cultivars.

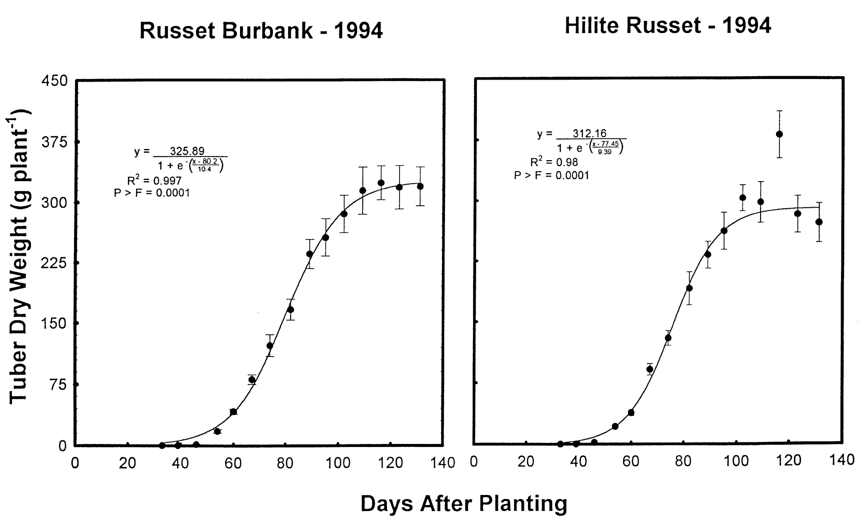

Figure 1. Pattern of dry matter accumulation in tubers of two potato cultivars during the 1994 growing period. Vertical line at each data point represents the standard error of the mean.

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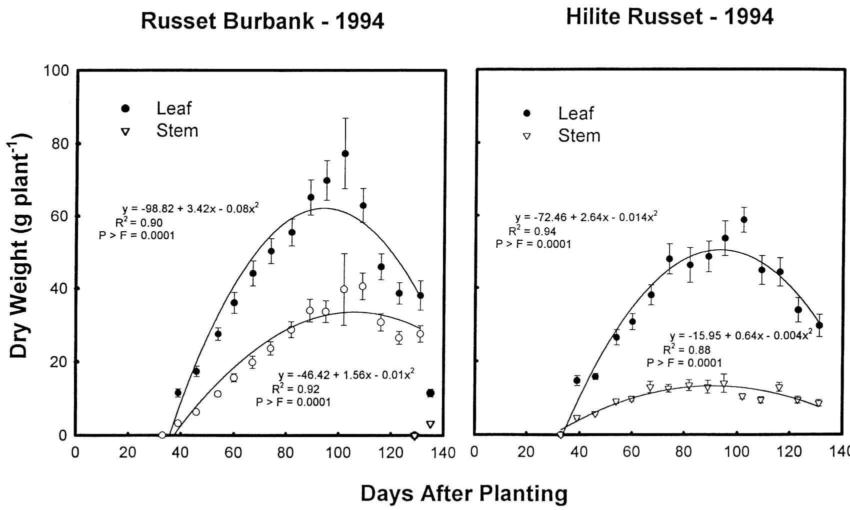

Figure 2. Pattern of dry matter accumulation in leaf and stem of two potato cultivars during the 1994 growing period. Vertical line at each data point represents the standard error of the mean.

Nitrogen uptake pattern followed quite similar trends as that of the dry matter accumulation. The tuber N content increased rapidly from 60 to 100 days after planting (Fig. 4). The increase in leaf N content preceded that of the tuber N content (Fig. 5). However, about 60 days after planting, N accumulation in the tuber increased rapidly as compared to that in the leaves. The N content in the leaves decreased rapidly beginning about 100 days after planting due to senescence. During the peak growth period, prior to senescence, the total N in all plant parts except the root accounted for up to 350 kg ha^{-1} in both the cultivars. The major portion of total N in the plant was located in the tuber, which represents the net N removal by the crop since only tubers are removed from the field (Fig. 6).

The changes in total N content in the plants are discussed using the 1994 data on Hilite Russet. The total N content in the plants peaked in July which accounted for 347 kg N ha^{-1}. Of this total amount, 240 kg was in the tuber, followed by 67 and 40 kgs in the leaves and stems, respectively. This represented 69.2, 19.3, and 11.5% of total N in the tubers, leaves and stems, respectively. By August, the total N content in the plants decreased to 251 kg ha^{-1} due mainly to extensive leaf senescence. The partitioning of N in the plant in August indicated 228 and 23 kg N ha^{-1}, respectively, in the tuber and stem. This represented 90.8 and 9.2%, of total N in tubers and stem, respectively.

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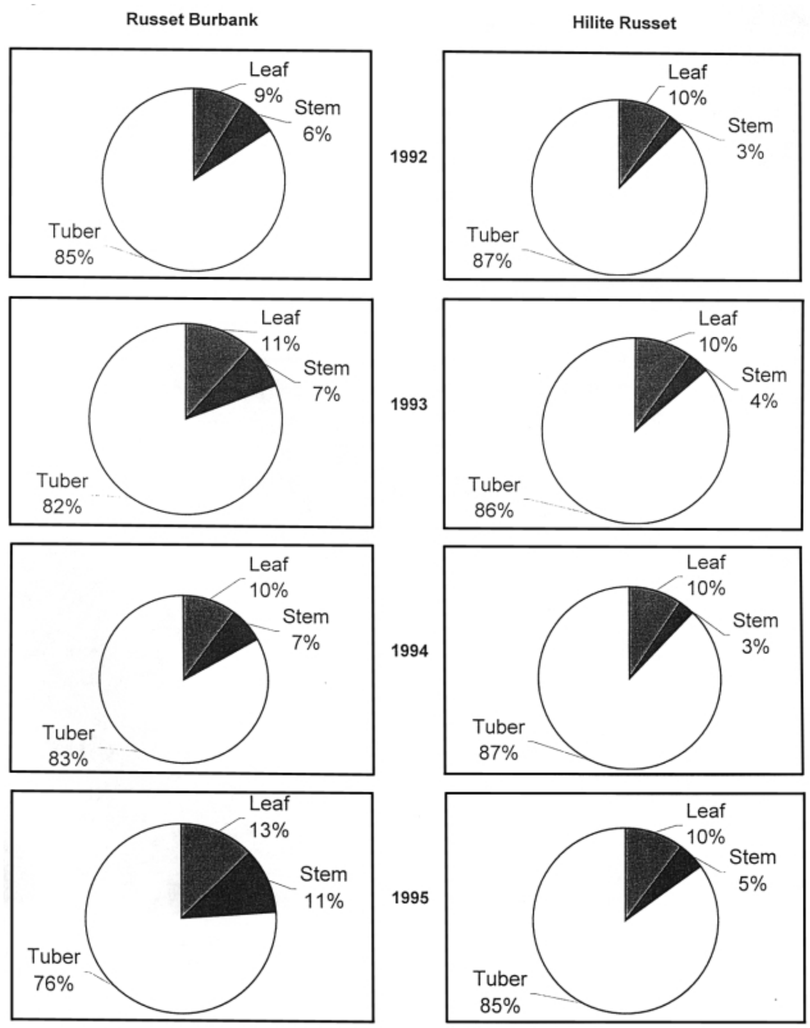

Figure 3. Final tuber, leaf, and stem dry weights as % of total plant dry weight of two potato cultivars during the four years, i.e., 1992 through 1995.

The plant residue returned to the soil is quite appreciable in July which could be rapidly decomposed and mineralized with release of available N forms. Since there is very little N uptake at this growth stage, the fate of N released is quite questionable. At full plant maturity, however, the N component in the plant residue is quite minimal.

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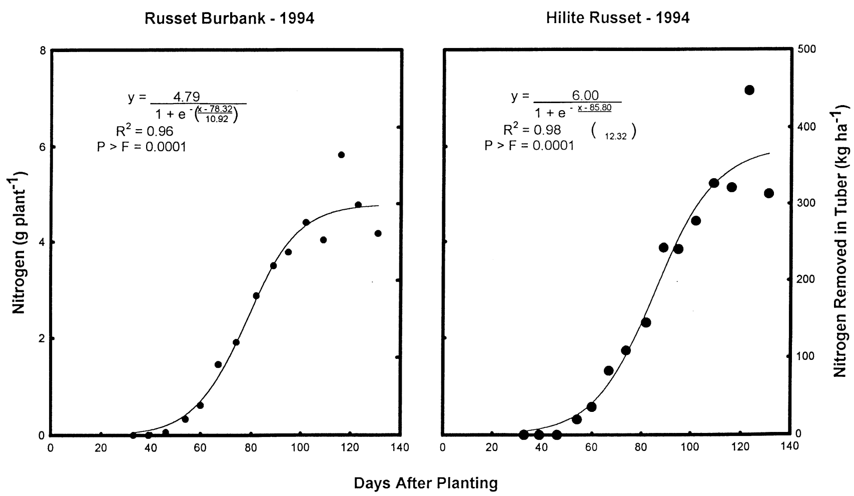

Figure 4. Pattern of nitrogen accumulation in tubers of two potato cultivars during the 1994 growing period. Vertical line at each data point represents the standard error of the mean.

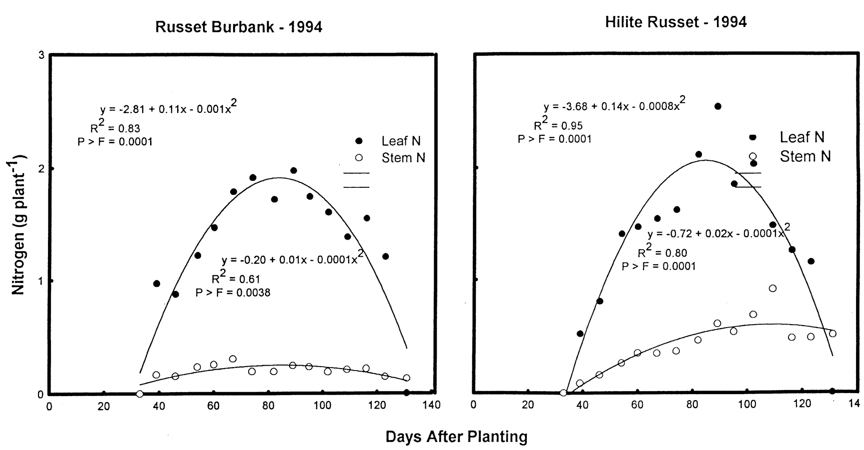

Figure 5. Pattern of nitrogen accumulation in leaf and stem of two potato cultivars during the 1994 growing period. Vertical line at each data point represents the standard error of the mean.

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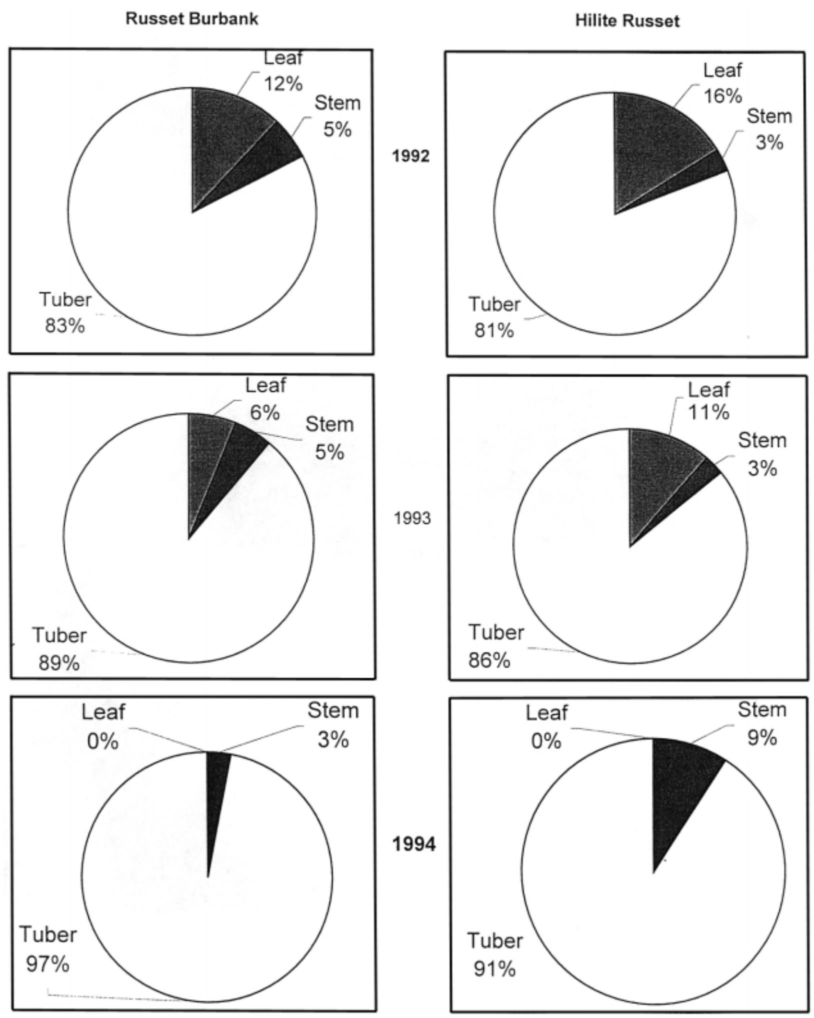

Figure 6. Partitioning of total plant nitrogen into tuber, leaf, and stem of two potato cultivars during three years.

Potatoes are generally grown in one out of three to four years rotation. Therefore, the contribution of potato plant residues plays a minor role in relation to nutrient management of potato production. The most common crops in rotation are either corn or wheat. The residue for the later crops upon decomposition and subsequent mineralization can produce a substantial portion of available N which

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can contribute to the nutrient requirements of potato in rotation. A parallel study has determined the N released by mineralization of corn and wheat residues during May through September, can account for up to 76 kg N ha^{-1}.[11]

The net nutrients removed by the tuber can also be calculated based on the nutrient concentrations in the tuber and the target tuber yield. The published data show that the N content per ton (Mg) of tuber can vary from 2.6 kg [12,13] to 3.2 kg [14], and as high as 4.2 kg.[15] Using the above tuber N content data and considering a production of 67 Mg ha^{-1} (600 cwt tuber per acre, which is the average production in the Columbia Basin region in the Pacific Northwest), the total N in tubers would account for 175, 215, and 282 kg ha^{-1}, respectively. Using the total N concentrations in the tuber at plant maturity, the calculated N removal in the tuber in this study ranged from 250 to 280 kg ha^{-1}, which is within the range of values reported in the literature.

Westermann et al.,[16] conducted N recovery studies on Russet Burbank grown in a Portneuf silt loam soil (coarse-silty, mixed, mesic Durixerollic Calciorthids). During the peak growth stage, they reported total plant N uptake of about 300 kg ha^{-1} in plants which received 162 kg N ha^{-1} preplant application and 180 kg N in season as four applications of 45 kg ha^{-1} each. Roberts et al.,[17] conducted a labeled N study on Russet Burbank cultivar grown in a Quincy loam sand (mixed, mesic Xeric Torripsamments) with 336 kg ha^{-1} seasonal total N, applied as 112 kg ha^{-1} preplant and the remaining quantity as 10 applications in season. They reported maximum recovery of 61 to 67% of applied N by the plant over the entire season.

ACKNOWLEDGMENTS

We appreciate the cooperation and assistance by AgriNorthwest Company for this study. We are also thankful to J. Cochran, J. Aarstad, M. Copenhaver, M. Seymour, and M. Wilson for their assistance during the course of this study and manuscript preparation.

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